

Research Note

Talking While Signing: The Influence of Simultaneous Communication on the Spoken Language of Bimodal Bilinguals

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ABSTRACT

Purpose: This study aimed to examine how speech while sign (simultaneous communication [SimCom]) affects the spoken language of bimodal bilingual teachers and how individual differences in sign-language vocabulary knowledge, SimCom teaching experience, and the ability to perform speech under dual-task conditions explain the variability in SimCom performance.

Method: Forty experienced teachers of deaf and hard of hearing students participated in a story narration task under different conditions. Speech rate, lexical richness, and syntactic complexity were measured and compared across speech-only versus SimCom conditions. Furthermore, participants' score on a sign-language vocabulary test, their self-reported SimCom teaching experience, and their performance in a dual-task condition were taken as predictors of SimCom narration performance.

Results: The findings revealed slower speech rate, lower lexical richness, and lower syntactic complexity in the SimCom condition compared with the speech-only condition. Sign-language vocabulary score and SimCom teaching experience explained speech rate and lexical richness. Participant's ability to speak under a dual-task condition did not modulate performance.

Conclusions: The findings may suggest that the production of the less dominant (sign) language during SimCom entails inhibition of the dominant (spoken) language relative to the speech-only condition. At the same time, the findings are also compatible with the suggestion that SimCom serves as a unique complex communication unit that cannot be reduced to the combination of two languages.

Unlike spoken languages, which are produced at the vocal tract and are perceived by the auditory system, sign languages use the hands for production and the visual system for perception. This significant modality difference allows speakers the theoretical opportunity to produce and perceive a spoken and a signed language at the same time (Emmorey et al., 2008). Indeed, studies show different patterns of mixed language productions, such as incorporating spoken features into signs, combining spoken words with the sign-language structure ("coda-talk"), and code-blending when individual

signs that are semantically and temporally aligned with the accompanying words are signed while talking (Morford & Kroll, 2021). Interestingly, spoken and signed languages can also be continuously produced at the same time. Such simultaneous production is the core feature of simultaneous communication (SimCom), which is the focus of this study.

SimCom

SimCom was developed for the Deaf education system in the United States in the 1970s, aiming to improve the spoken language of deaf and hard of hearing students (DHH), by representing it manually (Tevenal & Villanueva, 2009). It was used along the years with other populations such as children with intellectual disabilities (Kahn, 1981). In

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SimCom, the spoken language is produced and serves as the frame, along with a sequence of signs (drawn from the sign-language lexicon used by the community), which are produced simultaneously (Spencer & Tomblin, 2006). Previous studies show that teachers of DHH are able to represent a high percentage of the spoken message in SimCom (Hyde & Power, 1991; Luetke-Stahlman, 1988). For example, Luetke-Stahlman (1988) followed 12 hearing teachers of DHH in their classrooms and found that nine of them maintained most of the spoken meaning (> 72%) during SimCom. Hyde and Power (1991) examined four teachers of DHH and found that they were more than 90% accurate in translating their speech into sign. Nonetheless, some previous research has demonstrated that during SimCom, the outputs of the spoken and the signed messages are not equivalent (Tevenal & Villanueva, 2009). Moreover, the finding that both languages can in principle be produced simultaneously leaves open the question of whether and how such simultaneous production affects the characteristics of the spoken language, relative to a situation in which a single language is produced. Here, our focus is on characterizing production of Hebrew as the spoken language produced under SimCom conditions, in which Israeli Sign Language (ISL)¹ is incorporated.

Educational and Theoretical Importance

Characterizing the spoken language that is produced under SimCom conditions is both educationally and theoretically relevant. On the educational front, SimCom is widely used in the educational system of DHH (e.g., Woodward & Allen, 1987) based on the rationale that equivalent information will be communicated directly and simultaneously (Tevenal & Villanueva, 2009). As such, it is important to examine to what extent the spoken language input provided to DHH students under such conditions resembles that provided under single-language conditions.²

Furthermore, going beyond characterizing the spoken language under SimCom condition, this study also explores how speakers' abilities in the spoken and signed languages, as well as their ability to perform under dual-task conditions, modulate their SimCom behavior. This exploration holds promise to dissociate different theoretical accounts. Specifically, observed differences in the spoken language produced under SimCom conditions relative to speech-only conditions may be explained by three theoretical views. First, the *language inhibition view* suggests that production of one language requires inhibition of the other language (Green, 1998). This has been suggested to occur for the dominant language of

unimodal bilinguals, when producing their less dominant language (Morford & Kroll, 2021), and in bimodal bilinguals in the same direction (Emmorey et al., 2008). For example, Emmorey et al. (2008) observed code-blending when both signed and spoken languages were used, but only when the matrix language was the spoken language, suggesting that when producing the less dominant sign language, suppression of the dominant spoken language may have occurred. Of relevance, to the extent that SimCom entails simultaneous production of a dominant spoken language (in which individuals are more proficient) and linguistic representations drawn from a less dominant sign language, we may expect inhibition of the spoken language under such SimCom conditions.

Second, the *dual-tasking view* holds that SimCom entails production of linguistic representations from two languages in two modalities at the same time. As such, this process may be conceived of as involving a dual-task component, which has been shown to affect speech production (e.g., Kemper et al., 2009). For example, Kemper et al. (2003) examined how speech of younger and older adults was influenced by one of three dual-task conditions: walking, finger tapping, and ignoring speech or noise. They found that both age groups were affected by dual-tasking, with younger adults producing shorter and simpler sentences, and older adults demonstrating reduced speech rate. Thus, spoken language production may be affected by concurrently conducting a second task, and individuals may differ in the extent to which such dual-task conditions hinder their performance. As such, individuals' performance under dual-task conditions may modulate their performance under SimCom conditions.

Finally, one may conceive of SimCom as reflecting a whole complex unit (Kaufmann & Philipp, 2017), such that speakers acquire this mode of communication and gain proficiency and experience in it, independently of their abilities in the spoken or the signed languages. Supporting this *SimCom independence view*, Kaufmann and Philipp (2017) observed that switching between SimCom and single response (signed or spoken) was associated with a switch cost. They concluded that the SimCom condition had to be inhibited as a whole in order to activate just one of the languages. Of relevance, to the extent that SimCom operates independently, although the spoken language may differ from that of the speech-only condition, there is no reason to expect that individuals' abilities in Hebrew, ISL, or dual-tasking would modulate performance. This study, therefore, aims to characterize the spoken language produced under SimCom conditions, and to examine factors that may underlie variability in spoken language performance under SimCom conditions.

Previous Literature

Suggestive evidence that SimCom affects the characteristics of the spoken language come from studies that focused on single-word production. Specifically, in the study by

¹Note that Israeli Sign Language is a separate language from Hebrew, widely used in the Deaf community in Israel (Meir, 2014).

²It is similarly important to examine how the signed language input provided under SimCom conditions differs from that produced in sign language-only conditions, but this is beyond the scope of this study.

Kaufmann and Philipp (2017) mentioned above, the authors measured performance of bimodal bilinguals in a naming task that was performed in pure blocks of speech-only, sign-only, and dual-language conditions (a mixed block was also examined, but is not relevant here). Results showed longer naming times for pictures in the dual-language condition compared with the speech-only condition, but not compared with the sign-only condition. These findings can be explained with the notion of synchronizing lexical onset (Emmorey et al., 2012), by which speech production is delayed due to the need to synchronize onset of the spoken language with that of the (slower) manual response. Indeed, in a similar picture naming task, Emmorey et al. (2012) found that simultaneous production delayed speech production but did not slow lexical retrieval for sign language, and even facilitated access to low-frequency signs.

More direct evidence comes from a study by Whitehead et al. (2008) focusing on connected speech. In that study, they explored 10 participants communicating in SimCom versus speech-only conditions, and found that whereas prosodic rules did not differ between the two conditions, the sentences produced under SimCom were slower than those produced in the speech-only condition (see also MacKenzie et al., 2006).

Other studies observed differences beyond speech rate in the spoken language produced under SimCom versus speech-only conditions. Specifically, Newton (1985) observed reduced use of idiomatic English expressions in a SimCom condition versus speech-only condition among 10 teacher-student dyads. Furthermore, focusing on performance in only the SimCom condition of 23 teachers, Kluwin (1981) found avoidance of vocabulary and grammatical constructions that could not be easily represented by the sign system. This simplification of the spoken language under the SimCom condition was more pronounced for the more proficient teachers, presumably because these experienced teachers aimed for a more natural use of sign language, making it the matrix language and the spoken language the accompanying one. Note, however, that no direct comparison to a speech-only condition was available in that study. Wilbur and Petersen (1998) examined speech and sign production during SimCom and compared this condition to speech or signed English alone. In that study, participants frequently omitted function words in SimCom. Interestingly, native signers showed fewer omissions than nonnative signers, who used signed English. The authors suggested that signed English is inconsistent and thus does not support the grammatical structures of English, resulting in more omissions.³

Thus, syntactic differences between the spoken and the signed languages used during SimCom may affect spoken

language performance. Of relevance, Hebrew and ISL, the targeted SimCom languages in this study, differ syntactically. For instance, although both share subject-verb-object word order, subject-object-verb word order is common in ISL (Meir et al., 2017), but is ungrammatical in Hebrew. Furthermore, ISL and other sign languages are unique in how they sign arguments of verbs. For instance, Stamp et al. (2021) observed that deaf students produced grammatically correct simple sentences with object omissions in ISL by modifying features of the arguments using classifier handshapes. Interestingly, when the same sentences were produced in the spoken language, argument omissions also occurred, resulting in ungrammatical sentences. Thus, to the extent that spoken language is influenced not only by the accompanying signs but also by the underlying syntax of the signed languages, we may expect syntactic differences in the spoken language produced under SimCom relative to speech-only conditions.

This Study

Our first research question was, therefore, to test whether the spoken language produced during SimCom differs from that produced without accompanying signs. With a larger sample size than most previous research, in a controlled design, we tested speech rate, lexical richness, and syntactic complexity during a (more ecologically relevant) narration task. Focusing on the spoken language only, we predicted faster speech rate and higher lexical richness and syntactic complexity during the speech-only narration task compared with the SimCom narration task. These predictions are compatible with both the language inhibition and the dual-tasking views and are not at odds with the SimCom independence view. Specifically, if SimCom requires inhibition of the dominant (spoken language), then slower speech rate and lower lexical richness and syntactic complexity are expected under SimCom relative to speech-only condition, because all linguistic representations of the spoken language would be less accessible as a result of inhibition. Similarly, if SimCom poses demands of dual-tasking, slower speech rate and lower lexical richness and syntactic complexity are expected under SimCom than speech-only condition. Furthermore, the SimCom independence view does not preclude the possibility that some individuals would be less proficient in SimCom relative to their proficiency in the spoken language. Thus, observed differences in the speech-only relative to the SimCom condition would be of practical relevance, but would not serve to dissociate the theoretical explanations reviewed above.

To better dissociate the theoretical accounts, our second research question aimed to test what factors may explain individual variability in the ability to produce the spoken language under SimCom conditions. Of relevance, we aimed to test whether individuals' sign-language vocabulary, SimCom teaching experience, and the ability to produce speech under

³Indeed, Scott and Henner (2021) argued that signed English is still used in deaf and hard of hearing students' education despite the lack of evidence for its effectiveness for instruction.

dual-task demands can explain differences in spoken language performance between a speech-only condition and a SimCom narration condition. The language inhibition view predicts a relation between individuals' spoken and sign language proficiencies and their SimCom performance, because individuals with higher spoken-language proficiency should inhibit it more under SimCom conditions, and those with higher ISL proficiency should show less of a difference because its higher activation will already hinder performance in the speech-only condition. Thus, once speech-only performance is controlled for, SimCom speech rate, lexical richness, and syntactic complexity are expected to be modulated by spoken and sign language proficiencies. The dual-tasking view further predicts a relation between individuals' dual-tasking score and their SimCom performance. To the extent that SimCom entails the difficulty associated with performing two tasks simultaneously, individuals with higher ability to deal with dual-tasking should perform better in SimCom conditions once variability in speech-only condition is taken into account. Finally, the SimCom independence view does not predict any relation between individuals' SimCom performance and their experience in the spoken language or the sign language, or with their dual-tasking abilities. Instead, SimCom performance should mainly be predicted by long-term SimCom experience.

Method

Participants

Forty teachers (average age = 39.1, $SD = 13.74$) who work with DHH students participated in this study. They were Hebrew-ISL bimodal bilinguals who use SimCom daily as the means of communication in the classroom (see Table 1 for more information). They were recruited through personal communication and word of mouth and signed an informed consent to indicate their willingness to participate in the study, in accordance with the university's ethics protocol. Participants' language profile was assessed via a language history questionnaire (LHQ; adapted from the Language Experience and Proficiency Questionnaire [LEAP-Q]; Marian et al., 2007). All participants were females, born in Israel with Hebrew as their first and most proficient language. They were first exposed to ISL as adults as part of their work in the DHH educational system. Thus, the current group represents a particular bimodal bilingual profile, which is commonly found in the field.

Procedure and Materials

Overall Procedure

Each participant completed the experiment in one meeting. They were asked to tell four different stories, in four

Table 1. Participants' characteristics ($n = 40$).

Characteristics	<i>M (SD)</i>	
Age	39.10 (13.74)	
Education (in years)	16.05 (2.73)	
Years working with DHH students	13.65 (11.85)	
Working hours with DHH students today (hours per week)	26.48 (10.60)	
ISL vocabulary	27.28 (8.03)	
SimCom fluency ^a	16.90 (6.38)	
	Hebrew	ISL
Age of acquisition	0	23.72 (5.17)
Self-rated production proficiency ^b	9.18 (0.96)	6.45 (1.92)

Note. DHH = deaf and hard of hearing; ISL = Israeli Sign Language; SimCom = simultaneous communication.

^aThe average number of words produced within a given category, based on the category fluency task (see Procedure and Materials section). ^bReflects the average proficiency rating of language production (talk or sign) rated on a scale of 0 (*lowest*) to 10 (*highest*).

different conditions, as they would tell it to a child. The first two conditions, counterbalanced across participants, were the speech only (Hebrew), and the SimCom (Hebrew and ISL speech while sign) conditions. Note that the SimCom condition was not a signed Hebrew, but rather speaking while signing ISL (see the work of Scott & Henner, 2021, for the difference between the two sign systems), which is common in the educational system in which this study was conducted. The third condition was a dual-task, and the fourth was a sign only (ISL), which is not analyzed here. The order of the four stories used for the narration task was counterbalanced across participants. Following the (a) narration task, one of which in (b) a dual-task condition, participants completed (c) an ISL vocabulary knowledge task, which tested frequent vocabulary signs from the stories, (d) a SimCom fluency task, and (e) a detailed LHQ. The tasks were videotaped and transcribed for subsequent coding by a professional Hebrew-ISL interpreter.

(a) Narrative Production

Four stories of the "Frog Story" picture storybook series (Berman & Slobin, 1994) were used: "Frog, Where Are You?" (Mayer, 1969; 29 pages), "Frog on His Own" (Mayer, 1973; 27 pages), "Frog Goes to Dinner" (Mayer, 1974; 22 pages), and "A Boy, a Dog, and a Frog" (Mayer, 1978; 25 pages). During the narration phase, participants were presented with a large poster including the pictures of the specific story, to avoid the need for page flipping.

(b) Random-Typing Task

This finger tapping task was used to elicit a dual-task situation (e.g., Kemper et al., 2003). Following Declerck and Kormos (2012), participants were asked to type on a computer keyboard, each finger at a time, as randomly as possible. The

task was performed on a portable computer keyboard, while the screen was hidden by the storybook pictures' poster, such that participants were unable to see the outcome of their typing. Following Kemper et al. (2009), we monitored performance off-line on the motor task in order to verify that participants were indeed engaged in two tasks simultaneously. In prior work utilizing this task (Declerck & Kormos, 2012), the randomness of the task, indexed by the random number generation (Evans, 1978), was 0.4 in the dual condition (see also the work of Jahanshahi et al., 2006, for similar estimates of randomness). This index ranges between 0.00 (most random) to 1.00 (least random). In this study, the randomness of the finger tapping was $M = 0.49$, $SD = 0.14$, based on an analysis with the RGCALC computer software, which evaluates the order in a sequence of items (<https://www.lancaster.ac.uk/staff/towse/rgcpage.html>; Towse & Neil, 1998). There was no predetermined criterion for randomness, but we examined the distribution to identify outliers. All participants were retained as none deviated more than 3 SD s from the mean.

(c) Vocabulary Knowledge of Specific ISL Content

The task was developed to tap the vocabulary of the story narration task. It included a list of 50 Hebrew words (16 nouns, 17 verbs, 16 adjectives/adverbs, and one conjunction word), which were common words used in the story narrations of four adult native Hebrew speakers who narrated the four stories (and did not participate in the main experiment). Order of words was initially randomized and then kept constant. The experimenter read out loud each word, and participants were asked to sign it in ISL. Partial and incorrect sign responses received 0 point, whereas correct responses (including signed Hebrew) received 1 point.

(d) SimCom Fluency Test

Using a category fluency task (Marshall et al., 2013), each participant was asked to produce in SimCom as many signs as possible within a time limit of 60 s. The test included categories of foods and animals and was coded with the same coding system described in (c).

(e) LHQ

A modified Hebrew version of the LEAP-Q (Marian et al., 2007) was used, in which participants reported their levels of proficiency and use in each of the languages they know. Of relevance, participants indicated the number of years they have been teaching DHH students and the number of current hours a week they teach. These two variables, which jointly reflect SimCom teaching experience, were compiled into a single factor by adding the standard score of each measure. Thus, a teacher who has been teaching for many years and is currently teaching many hours a week scored higher on this measure, whereas someone who either teaches for only a few years, or who currently teaches

only a few hours a week, scored in the middle range of this new measure.

Coding and Analyzing

Story narrations were manually transcribed and coded with an automated text analysis tool developed by Ben-Simon and Cohen (2011) for scoring written essays in Hebrew (<https://hlp.nite.org.il/WebStatisticalAnalyzer.aspx>, Version 30/5/2018). Three central measures were computed: (a) *speech rate*, reflecting the number of words per second, measured by dividing the total number of words by the duration of the story (in seconds)⁴; (b) *lexical richness*, measured with the type-token ratio, including both the number of words (i.e., letter strings, tokens) and the number of unique words (types); (c) *syntactic complexity*, measured with the ratio of complex utterances including coordinates (e.g., “Dani halach lachalon vekara latsfardea” [“Dani walked to the window and called the frog”]) and subordinates (e.g., “hatsfardea akav achrei isha sheyashva bapark al safsal im hatinok shela” [“The frog followed a woman that was sitting in the park on the bench with her baby”]) out of the total utterances (Berman & Slobin, 1994).

Results

Mean performance by condition (speech only; SimCom) is provided in Table 2. Results were first analyzed using a set of one-tailed⁵ t tests to assert the initial hypothesis of a difference between participants' performance in the speech-only condition and the SimCom condition.⁶ Next, we used a regression model in order to identify the factors that

⁴The focus of our comparison was exclusively on the spoken language; thus, we did not include signs in our calculations. Note that bilinguals' performance in a single language does not necessarily represent their full communication ability, but these issues are beyond the scope of this study.

⁵Differences remained significant even when the more conservative two-tailed criterion of significance was imposed.

⁶Performance in the dual-task condition was examined only in order to extract an individual difference score reflecting dual-task performance, to be used as a predictor of SimCom performance. Nonetheless, for completeness, we provide information on performance in this task and compared with the speech-only condition; time in seconds $M = 198.93$, $SD = 73.48$, $t(39) = 1.53$, $p = .068$, $d = 0.24$; number of words $M = 258.75$, $SD = 104.83$, $t < 1$, $d = 0.05$; number of word types $M = 136.00$, $SD = 46.27$, $t < 1$, $d = 0.01$; speech rate $M = 1.35$, $SD = 0.37$, $t(39) = 2.80$, $p = .004$, $d = 0.44$; type-token $M = 0.54$, $SD = 0.07$, $t(39) = 1.45$, $p = .078$, $d = 0.23$; complex utterances (%) $M = 16.08$, $SD = 7.87$, $t < 1$, $d = 0.09$. The dual task condition did not differ from the speech-only condition, with the exception of speech rate, which was significantly faster in the speech-only condition. In addition, story time and the type-token ratio marginally differed between the dual-task and the speech-only conditions.

Table 2. Participants' mean performance in the three conditions (*SD*).

Measure	Condition		<i>t</i> (39)	<i>p</i>	Cohen's <i>d</i>
	Speech only	SimCom			
Time in seconds	182.73 (76.42)	231.28 (81.51)	-5.40	< .001	0.85
Number of words	262.23 (105.97)	235.9 (88.61)	2.21	.017	0.35
Number of word types	135.75 (48.4)	116.95 (37.67)	3.18	.002	0.50
Speech rate	1.47 (0.27)	1.05 (0.28)	10.86	< .001	1.72
Type-token	0.53 (0.05)	0.51 (0.06)	2.28	.014	0.36
Complex utterances (%)	16.79 (9.30)	12.96 (5.73)	2.58	.007	0.41

Note. SimCom = simultaneous communication.

may explain variance in SimCom performance after controlling for shared variance with the speech-only condition.

Differences Between Speech-Only and SimCom Conditions

As shown in Table 2 and Figure 1, “speech rate” in the speech-only condition was significantly faster than in the SimCom condition. Lexical richness measured by “type-token ratio” in the speech-only condition was significantly higher than in the SimCom condition. This significant difference was also observed when separately examining the two components of this ratio: “number of word tokens and number of word-types” (but note that the three measures are inherently linked). Furthermore, syntactic complexity, as measured by the “percent of complex utterances” out of all utterances, was found to be significantly higher in the speech-only condition compared with the SimCom condition.

Predicted Variance in SimCom Performance

To examine what explains the variance in performance in the SimCom condition, a regression model was conducted for each of the five possible dependent measures (speech rate, type-token ratio, number of word tokens, number of word types, and percent of complex utterances). As the first step, the comparable score in the speech-only condition was entered to control for baseline differences in Hebrew performance. Next, we examined how individual differences in ISL vocabulary knowledge, SimCom fluency, SimCom teaching experience, and the ability to perform under dual-task conditions modulate performance. These variables were entered as possible predictors in a stepwise manner. Specifically, to measure ISL vocabulary knowledge, we relied on the objective measure of ISL vocabulary score of signs that are frequent in the stories; to measure SimCom fluency, we used the single-word fluency task; to measure SimCom teaching experience, we used the composite score of years and hours of teaching experience with SimCom (see Method section); to examine the ability to produce language while conducting

a secondary manual task (i.e., a dual-task situation), we used the comparable score from the dual-task condition. Notably, we opted to refrain from using the subjective ratings of proficiency and use in ISL from the LHQ, as such self-report measures have recently been shown to be biased (Tomoschuk et al., 2019).

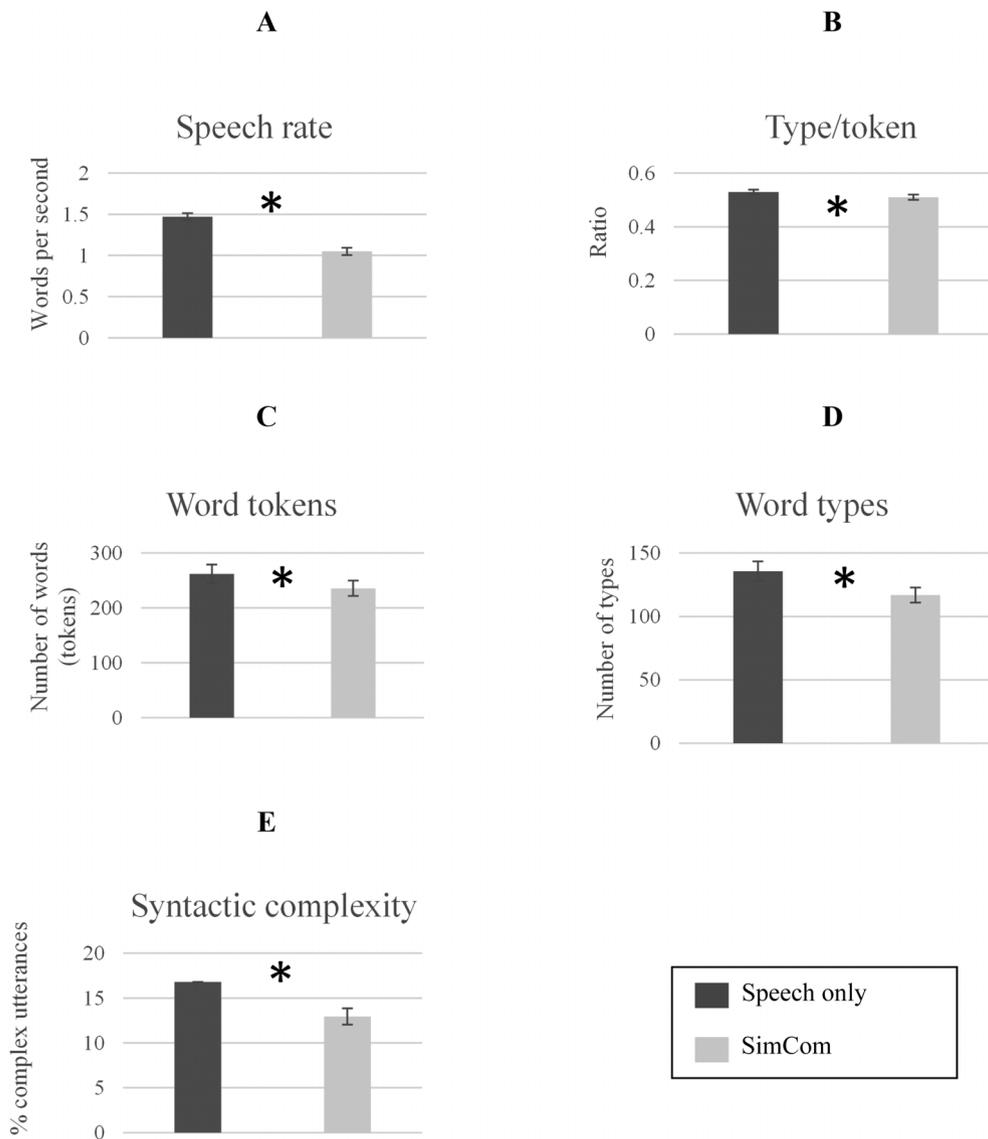
Of note, because performance in the speech-only condition was partialled out in the first step, variance explained by the different predicting factors reflects unique SimCom variance that is not shared with the speech only performance. As such, it reflects the difference between the two conditions.

Performance across different measures was significantly predicted by baseline performance in Hebrew, as measured by the comparable speech-only score (see Figure 2 for partial correlation *sr*). Specifically, this was the case for speech rate ($\beta = .58$; $t = 5.14$, $sr = .65$, $p < .001$), number of words ($\beta = .69$, $t = 6.23$, $sr = .72$, $p < .001$), number of word types ($\beta = .62$, $t = 5.19$, $sr = .65$, $p < .001$), and type-token ratio ($\beta = .61$, $t = 4.69$, $sr = .61$, $p < .001$). Performance in terms of the percent of complex utterances was only marginally predicted by the comparable speech-only score ($\beta = .29$, $t = 1.88$, $sr = .29$, $p = .067$). Interestingly, speech rate in the SimCom condition was further predicted by individuals' scores on the ISL vocabulary test ($\beta = .44$; $t = 3.93$, $sr = .54$, $p < .001$). Conversely, the number of words and number of word types were predicted by individual differences in SimCom teaching experience ($\beta = .24$, $t = 2.15$, $sr = .33$, $p = .04$; $\beta = .26$, $t = 2.22$, $sr = .34$, $p = .033$, respectively). As shown in Figure 3, participants with more teaching experience produced more words in the SimCom condition. Finally, the comparable score in the dual-task condition and the SimCom fluency score did not uniquely explain the variance in any of the measures.

Discussion

This study explored the characteristics of the spoken language produced during a SimCom situation by experienced teachers of DHH students. Story narrations were compared between a speech-only (Hebrew) and a SimCom

Figure 1. Performance in the speech-only condition versus the simultaneous communication (SimCom) condition. (A) Average number of words produced in 1 s; (B) type–token ratio: number of words divided by the number of word types; (C) overall number of words produced; (D) number of unique words (word types) produced; (E) percentage of complex utterances. Error bars represent standard errors. The asterisk marks a significant difference at the $p < .05$. Exact values can be seen in Table 2.

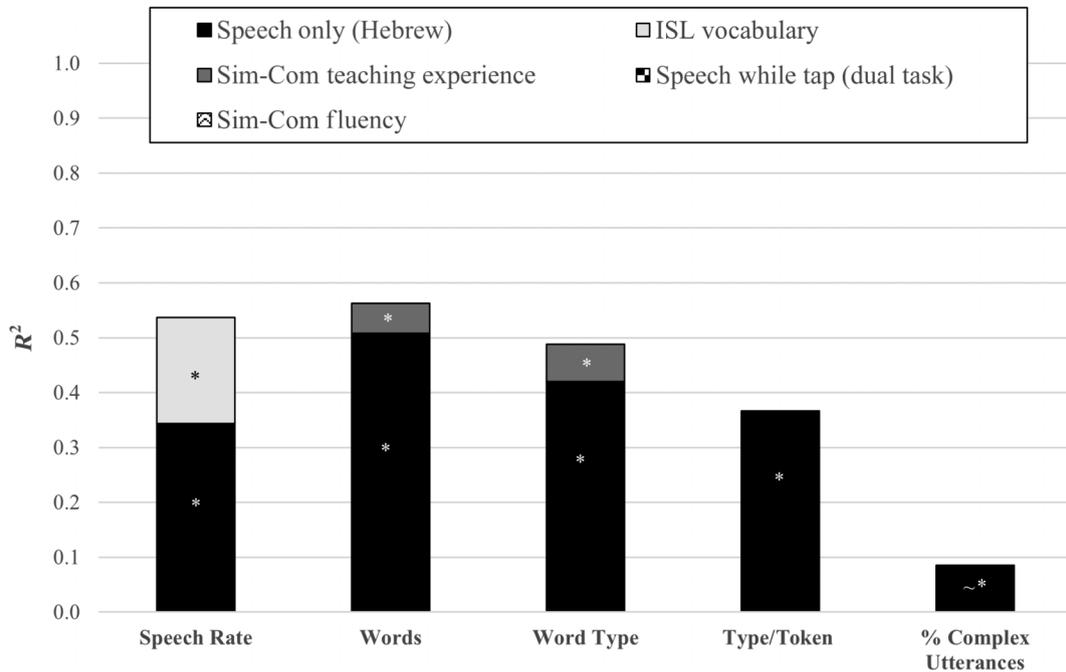


(Hebrew and ISL) conditions. Results revealed slower speech rate, lower lexical richness, and syntactic complexity in the SimCom condition relative to the speech-only condition. Furthermore, spoken language performance in the SimCom condition was explained by speakers' performance in the speech-only condition. Of relevance, individual differences in ISL knowledge of signs from the stories' content predicted SimCom speech rate, whereas SimCom teaching experience predicted the number of words and word types produced under a SimCom condition. However, these individual differences did not modulate more direct measures of lexical richness (type–token ratio) and syntactic complexity (percent of

complex utterances). Finally, single-word SimCom fluency and participant's ability to speak under dual-task conditions did not modulate performance. These findings are discussed below as they reveal the nature of SimCom performance.

The finding that Hebrew speech rate in the speech-only condition was significantly faster than in the SimCom condition is in line with previous studies observing longer sentence duration in a SimCom condition, compared with the same sentences produced in a speech-only condition (MacKenzie et al., 2006; Whitehead et al., 2008). Our findings extend these experiments to a more naturalistic narration task. Of interest, this study showed that speech rate in SimCom

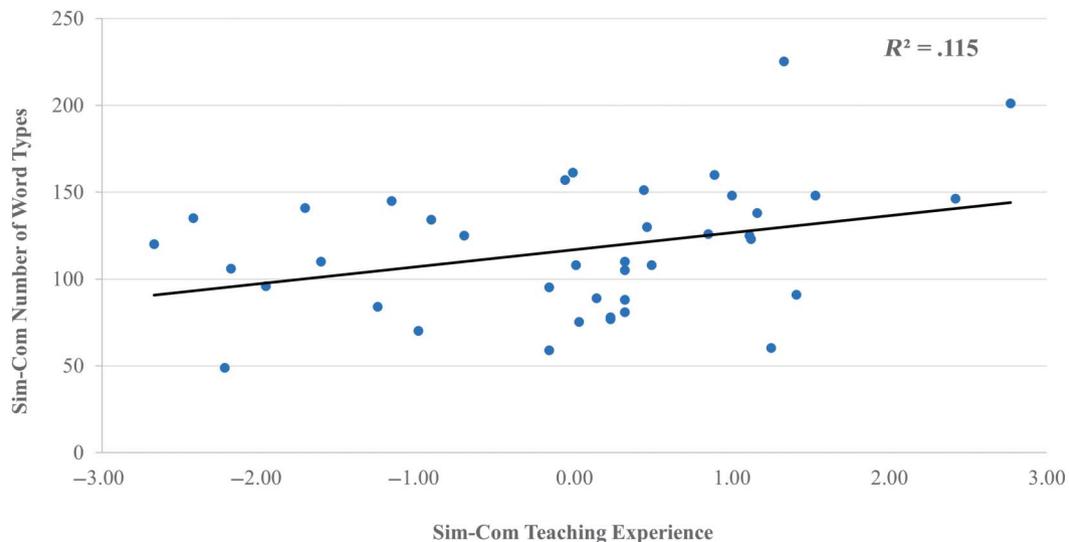
Figure 2. Proportion of explained variance (R^2) in each parameter according to the regression model. SimCom = simultaneous communication; ISL = Israeli Sign Language. * marks a significant contribution; ~* marks a marginally significant contribution.



was explained by ISL vocabulary, beyond performance in the speech-only condition. We suggest that lexical knowledge in sign language, and specifically of signs related to the tested stories, may constrain the ability to simultaneously produce speech while using sign language. This suggestion is consistent with the notion of synchronizing lexical onset (Emmorey

et al., 2012). Here, it appears that teachers with increased ISL vocabulary of the specific content that was required in the narratives were able to produce the spoken language at a higher rate in a SimCom situation, presumably because sign language lexical representations were more available, compared with teachers with lower ISL vocabulary scores.

Figure 3. The correlation between teaching experience and the number of word types produced in the simultaneous communication (SimCom) condition.



In addition, the results revealed the use of fewer words, and fewer word types, in the SimCom condition relative to the speech-only condition. Correspondingly, lexical richness, as measured by the type–token ratio was lower in the SimCom condition relative to the speech-only condition. These results are consistent with previous findings showing the avoidance of some vocabulary and grammatical constructions in a SimCom condition (Kluwin, 1981). However, the interpretation of previous studies was that these instances of avoidance stemmed from the difficulty in signing particular vocabulary and grammatical constructions. In contrast, in this study, there was no relation between ISL vocabulary score of signs that are frequent in the stories and the number of words produced in the SimCom condition. Thus, it was not the case that individuals with fewer ISL vocabulary exhibited larger decreases in lexical richness during the SimCom condition relative to the speech-only condition. That being said, more sensitive measures of ISL lexical knowledge may be better able to capture and explain complex connected speech behavior in a SimCom situation.

In this study, the number of words and the number of word types produced in a SimCom situation were modulated by participants' overall SimCom teaching experience, such that more experienced teachers produced more words in the SimCom condition. Kluwin (1981) also observed modulation of SimCom performance as a function of teaching experience, but he found that the avoidance of words in a SimCom condition was more prevalent for more proficient teachers, and suggested that this is because more experienced teachers bias their productions toward the signed language. Differences in defining teachers' SimCom experience may explain this differential pattern across studies. Specifically, while Kluwin (1981) measured the experience level by years of using sign language, this study employed an arguably more sensitive measure taking into account both the number of years and the number of hours per week using SimCom in an educational context. With this measure, increased SimCom teaching experience was associated with higher performance in the SimCom condition. Another explanation for the difference in the findings between Kluwin's (1981) study and this study pertains to potential differences in the profile of the DHH students who are the target audience of SimCom. In the last few decades, since cochlear implants became more prevalent, hearing function and speech perception of DHH students have improved (Geers & Nicholas, 2013). Therefore, the ability of DHH students today to rely on the spoken language might reduce their need to rely on sign language. This, in turn, may have caused the experienced teachers in this study to base their communication more on the spoken language, as opposed to the experienced teachers in Kluwin (1981) who based their communication on sign language. It remains to be examined how students' profile affect the dominance of spoken and signed languages during SimCom in

the classroom. Furthermore, this study did not explore the influence of SimCom in various educational settings and across developmental contexts (Maxwell, 1983; Scott & Henner, 2021). More generally, this study did not directly test how teachers' productions translate to students' performance, and there is evidence to suggest that these aspects are not always aligned. For instance, Maxwell (1983) observed that students' story writing was not improved with the signed English used by their teachers. Moreover, it is possible that in real-life situations, in the presence of real students, the productions of the teachers would be slightly different than those observed in a structured task. Future studies in which SimCom is examined in even more naturalistic settings would be informative, both with respect to teachers' output and with respect to the students' ability to benefit from that input. Furthermore, the degree to which these findings replicate in a one-on-one setting, such as the interaction that characterizes intervention by speech-language-pathologists or allied clinicians remains to be examined, both with respect to the characteristics of the language produced by such clinicians and with respect to children's ability to benefit from these productions.

This study is unique in its focus on syntactic performance in a SimCom condition. With the exception of the early study of Kluwin (1981), previous research did not examine syntactic performance in such a dual-language production situation. Our results show that spoken language performance in the speech-only condition was associated with higher syntactic complexity than that of the SimCom condition. Teachers produced more coordinate and subordinate sentences in the speech-only condition compared with the SimCom condition. This finding suggests that although by definition, SimCom entails using the syntax of the spoken language, simultaneously producing signs may lead speakers to incorporate lower syntactic complexity in their spoken language productions.

Despite this observed difference, none of the individual difference measures used in this study were able to explain unique variance in syntactic complexity under a SimCom condition above baseline differences in the speech-only condition (which only marginally explained behavior). To understand this pattern, it is important to keep in mind that none of the predictors in this study were direct measures of syntactic ability in ISL, as opposed to the ISL vocabulary task that tapped ISL signs from the tested stories more directly. However, the type–token lexical richness measure was also not explained by individual differences, raising the possibility that reduced power played a role in the lack of observed modulations. Future studies using direct measures of syntactic knowledge in sign language (e.g., Henner et al., 2019; Novogrodsky et al., 2017), and larger samples, may better elucidate what individual differences explain characteristics of the spoken language under SimCom performance.

Theoretical Implications

Across multiple measures, this study revealed differences between SimCom and speech-only narration performance. Specifically, slower speech rate, lower lexical richness, and lower syntactic diversity of the spoken language were observed in the SimCom condition compared with the speech-only condition. These findings are predicted by the *language inhibition* and the *dual-tasking* accounts, but are also compatible with the *SimCom independence* account. Thus, the mere difference in spoken language performance between conditions is not sufficient to dissociate between the accounts. However, the individual difference analyses shed some light on these issues.

In particular, under the dual-tasking account, we predicted that individuals' ability to perform under dual-task conditions would correlate with SimCom performance. In contrast to this prediction, performance in SimCom was not modulated by the ability to speak while conducting a secondary task (i.e., tapping in the dual-task condition), suggesting that participants did not experience the SimCom condition as an extra load dual-task condition created by combining two languages.⁷

Furthermore, the language inhibition and dual-tasking views predicted a relation between SimCom performance and speakers' spoken language and sign-language abilities. In contrast, under the SimCom independence account, we did not predict SimCom performance to be modulated by participants' ability in the spoken language and the sign language, under the assumption that these are independent modes of communication. Instead, experience with SimCom as its own communication mode was expected to modulate performance. Our results are inconclusive here. On the one hand, we found that increased SimCom teaching experience was associated with more words and more word types in the SimCom condition, suggesting a link between experience with SimCom and performance. Furthermore, fluency in SimCom was not associated with SimCom performance. However, we did observe that ISL vocabulary modulated speech rate under SimCom conditions, and that performance in the speech-only condition modulated SimCom across multiple measures. Thus, SimCom performance appears to be modulated both by speakers' long-term experience with this particular mode of communication, and with their independent abilities in the spoken and

signed languages. More research is therefore needed in order to better dissociate these theoretical views.

Together, the pattern of results observed here does not fully support one theoretical view over the other, but does provide important constraining evidence and highlights for future research. Whereas, the full pattern of results is consistent with the language inhibition account, the lack of predictive power of the dual-task condition weakens the dual-tasking view. Furthermore, the SimCom independence view receives some support by the predictive power of SimCom teaching experience, but is also weakened by the relation between sign and spoken language abilities and SimCom performance.

One way in which future research may be informative in this respect is by utilizing shifting across communication modes (see, e.g., block order manipulation by Kreiner & Degani, 2015). Specifically, recent work suggests that shifting between languages affects bilinguals' performance (e.g., Kreiner & Degani, 2015; Stasenko & Gollan, 2019). For instance, Russian–Hebrew bilinguals exhibited more lexical retrieval difficulties (more tip-of-the-tongue) in Hebrew after passively watching a 10-min Russian movie, compared with their performance prior to the movie. In the current context, this may suggest that the patterns of language use of teachers throughout their workday (e.g., in the classroom vs. in the teacher lounge/during breaks) may affect their in-class productions. Of relevance, the three theoretical proposals make differential predictions in this case. The language inhibition account predicts that communicating in the spoken language prior to using SimCom should act to enhance spoken language production during SimCom as this language would be more active and available. In contrast, the independence of SimCom proposal makes the opposite prediction, namely, that shifting from the spoken language to SimCom is akin to a shift between languages (e.g., between Hebrew and Russian, as per Kreiner & Degani, 2015), which might thus lead to reduced SimCom performance relative to a situation where the spoken language was not recently activated. Finally, the dual-tasking view predicts that recently using the spoken language should not affect performance in the dual-task SimCom situation. Future research utilizing such shifting manipulations may thus inform theoretical explanations of SimCom performance.

A few additional aspects should be noted with respect to the current findings. First, the fact that single-word SimCom fluency did not uniquely explain performance in the SimCom condition suggests that performance cannot be reduced to variability in single-word processing, and highlights the need to examine SimCom performance in ecologically valid connected speech situations. Furthermore, all teachers in this study were hearing, second language learners of ISL in adulthood. Generalizing the current results to teachers who are deaf themselves and teachers who are native signers awaits future studies.

⁷It is important to keep in mind that participants performed the dual-task condition as the third story. It is thus possible that they have gained more experience with the narration task by the third story, such that the task was not sensitive enough to individual differences in dual-task ability. Note that the critical speech-only and SimCom conditions were counterbalanced as the first and second stories, allowing direct comparisons between them.

Finally, future work in which the differences between sign-only and SimCom conditions will complement the work described here.

Educational Implications of Using SimCom

The results of this study are important in the educational context. The main goal of the SimCom method is to improve the acquisition of the spoken language of deaf students by representing it manually. However, this study revealed that the same teachers produce the spoken language with slower speech rate, lower lexical richness, and lower syntactic complexity in a SimCom relative to a speech-only condition. At face value, this may suggest that the linguistic input experienced by DHH students is reduced than that experienced by students who receive speech-only input. However, it is possible that the slower speech rate in the SimCom condition, and the reduced lexical richness and syntactic complexity of the spoken language in this communication method are in fact optimal for spoken language acquisition by DHH students. Thus, the results of this study serve as the basis for further investigation into the way in which the characteristics of the spoken language in a SimCom condition are perceived by the target audience of DHH students as a group and as individuals.

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